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The Role of 1-methylcyclopropene (1-MCP) in Improving the Postharvest Quality of Some Cut Rose Cultivars

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Abstract

In order to improve the postharvest quality and the export ability of cut rose (*Rosa hybrida* L.) cvs. Happy Hour and Bordeaux, the effect of 1-methylcyclopropene (1-MCP) as an ethylene inhibitor, was investigated. 1-MCP was used at 0.3, 0.4, 0.5 and 0.6 g m^{-3} for 18 h at 8 °C to simulate the transport of flowers. 1-MCP treatment significantly prolonged the vase life and minimized the weight loss of both cultivars compared to the control, however the response of Happy Hour cultivar was higher than the Bordeaux cultivar. 1-MCP treatment enhanced the relative water content (RWC) of flowers. The treatment of 1-MCP significantly retarded the degradation of chlorophyll and carbohydrate contents during vase life evaluation in both cultivars. The ethylene production was significantly decreased by applying 1-MCP treatment. The membrane stability index (MSI) was maintained while malondialdehyde (MDA) was decreased in response to 1-MCP treatment. The best treatments in this concern were 1-MCP at 0.4 and 0.5 g m^{-3} for Happy Hour and Bordeaux cultivars, respectively. 1-MCP treatment was recommended to inhibit the negative effects of ethylene on rose cultivars tested.

Keywords: Ethylene, Membrane stability, Postharvest, Rose, Vase life, 1-MCP.

INTRODUCTION

Postharvest of rose flowers has been engaging the attention of growers and researchers for many years. Understanding the variable postharvest performance of rose is important not only for ensuring maximum life of those that presently are of commercial importance, but also for developing new selections with improved postharvest quality. Rose flowers are mainly grown in countries where labor is cheap and the climate offers relatively favorable conditions such as Colombia, Ecuador, Kenya, Zambia and Zimbabwi. The markets of flowers, however, are mainly in countries where the standard of living is relatively high as is the flower consumption per capita such as North America, Japan, Netherlands and Germany (Hassan *et al.,* 2004).

The problem with the distribution is that flowers nowadays have to be transported all over the world. The cost of air shipment of flowers is a major factor influencing profitability in the flower trade. There is a big difference in the costs between airfreight and sea shipment. To achieve these savings, the vase life of flowers must be extended to provide the consumer with equivalent flower quality (Zeltzer *et al*., 2001). Cut flowers are often exposed to ethylene during production, transport, storage or retail marketing. Moreover, unfavorable transport conditions, such as high temperature, high humidity, darkness, and shaking in the truck, can reduce the vase life of cut roses as a result of endogenous ethylene produced in response to stresses in the postharvest environment. Some deleterious effects of ethylene exposure include leaf yellowing, flower (or petal) drop, irregular opening and premature death (Nowak and Rudnicki, 1990). It has been known for years that many roses are ethylene sensetive. The sensitivity to ethylene has important implications during the transport and handling the cut roses in supermarkets and other areas where the air is commonly contaminated with ethylene. The symptoms of ethylene are exaggerated when put under the stress of mass market condition and there were marked differences in sensitivity and response to ethylene among cultivars (Serek, 1993; Muller *et al*., 1998).

Faragher *et al*. (1987) and Mor *et al.* (1989) showed that cut roses produce substantial amounts of ethylene in response to stresses such as cold storage. Moreover, there were significant differences in the longevity of a range of commercial cultivars of roses. This variation in display life partly appeared to be a result of differences in ethylene production or sensitivity to ethylene exposure (Muller *et al*., 1998). There is a marked confusion over the role of ethylene in rose senescence, as Woltering and Van Doorn (1988) found that the sensitivity of roses to ethylene was very low until the flower was fully open for several days and the same authors reported that, in roses too, exposure to ethylene accelerates the abscission of petals suggesting that sensitivity to ethylene in rose flower is relatively high (Kumar and Srivastava, 2008). Furthermore, Reid *et al*. (1989 a, b) commented that ethylene does not appear to be an important natural regulator of the postharvest life of cut roses, however 1-MCP treatment as an ethylene inhibitor extended the vase life of cut roses (Hassan *et al.*, 2004) and exogenous ethylene inhibit opening in cut roses (Tan *et al*., 2006). Ethylene control is an important factor in the flower storage and shipping environment. The efficient ethylene action inhibitor (1-MCP) competitively blocks the hormone action of ethylene, by its irreversible binding to the ethylene receptor (Sisler and Serek, 1997).

Although ethylene supposedly play an effective role in rose wilting, there is limited information in the literature on the effect of 1-MCP on rose cut flowers but there is some information about potted roses. 1-MCP, even at very low concentrations, has been shown to eliminate the effects of ethylene on abscission and wilting of potted roses and hence, extended the shelf life (Muller *et al.,* 2000; Serek *et al*., 1996). There were differences in display life, chlorophyll loss, leaf and bud drop between potted rose cultivars in response to ethylene (Muller et al., 1998). Pretreatment with 1-MCP before transport simulation improved display life of two cultivars of miniature roses (Muller *et al*., 2000).

1-MCP has been found to be a very potent inhibitor of ethylene action in different cut flowers (Uthaichay *et al*., 2007; Hassan *et al*., 2004; Celikel *et al.*, 2002; Picchioni *et al*., 2002). All of these cited articles, as well as others, clarified the potential of using 1-MCP for maintaining the quality of cut flowers during storage and vase life. Hunter *et al.* (2004) mentioned that the involvement of ethylene in senescence of some flowers is still unclear and may depend on cultivar. However, little is known on retarding the senescence of rose cut flowers and not much information is yet available regarding the

use of 1-MCP to retard ethylene dependent senescence processes for various cultivars. There is a compelling need to find the optimum dose of 1-MCP for each cultivar. 1-MCP treatment may be results in a significant increase in the vase life allowing maximizing the postharvest quality as well as the export ability of cut roses. Therefore, the aim of this study was to investigate the effect of 1-MCP treatment on the vase life and postharvest quality measurements of (*Rosa hybrida* L.) cvs. Happy Hour and Bordeaux.

MATERIALS AND METHODS

Plant materials

Cut flowers used in the experiment was *Rosa hybrida* L. cvs. Happy Hour and Bordeaux. Flowers were brought to the laboratory as soon as possible and lower leaves were removed and the flowering stems were trimmed to a uniform length of 45 cm. The experiments were repeated twice and data were combined.

1-MCP treatment

Pre-treatment with 1-MCP was released from a commercial powdered formulation (EthylBlock, Rohm and Haas Italy, Inc.) by adding distilled water, according to the manufacturer's instructions. The flowers of each cultivar were placed inside a tight container for each treatment and the concentrations of 1-MCP were calculated as g m^{-3}. The concentrations of 1-MCP used were 0.3, 0.4, 0.5 and 0.6 g m^{-3} for 18 h and was conducted at 8 °C for all treatments to simulate the transport of the flowers. The control flowers were placed in identical container for the same period without 1-MCP. After the treatments the flowers were aerated and placed into glass vials containing 500 ml tap water for the vase life evaluation. Five treatments with three replicates for each cultivar were applied and each replicate consists of 10 flowers.

Vase life evaluation

The longevity of rose cut flowers was determined in a vase life evaluation room at 23 ± 1°C and 60 – 70 % RH. Visual rating of flowers was evaluated on a scale from 1 to 4 when: 1 = entirely fresh flowers, 2 = initiation of wilting in 20% of petals and beginning of bent neck, 3 = wilting in 20–50% of petals and increasing the bent neck, 4 = wilting in 50–100% of petals. The longevity of rose cut flowers was defined as the number of days in vase life required for 50% of the flowers to reach stage 2 or more advanced stages.

Fresh weight measurement

The stems of rose cut flowers were initially weighed at the beginning of the experiment. The fresh weight was repeated again at the end of vase life of control flowers (after 3 and 4 days for Happy Hour and Bordeaux cultivars, respectively). The fresh weight of each flower was expressed relative to the initial weight to represent the weight losses percentage.

Relative water content (RWC)

Flower RWC was determined and calculated from the following relationship:

$(W_{fresh} - Wdry) / (W_{turgid} - Wdry) \times 100$, where W_{fresh} is the sample fresh weight, W_{turgid} is the sample turgid weight after saturating with distilled water for 24 h at 4 °C, and Wdry is the oven-dry (70 °C for 48 h) weight of the sample (Weatherley, 1950).

Chlorophyll determination

Chlorophyll content of leaves was extracted by acetone from samples of cut leaf segments (0.5 g) taken on the 1st, 3rd, 5th and 7th days from the beginning of the experiment. Extraction in acetone was repeated until all pigments were extracted. The absorbance of the extracts was determined by a spectrophotometer (type GBC, UV/VIS 916, Australia). The chlorophyll content was calculated as mg g^{-1} fresh weight according to Dawood, (1993).

Carbohydrate content

The soluble carbohydrate contents were determined in the flower petals. The samples were

taken in the same time of chlorophyll determination. The carbohydrates were separated by HPLC system. Differential refractometer (Type: RIDK-2, Praha, Czech Republic) was used to detect of carbohydrates. Peak identity was confirmed using authentic carbohydrates. Peak area was determined by an integrator and the percent of each carbohydrate in the sample was calculated by a computer. The carbohydrate contents were calculated as mg g^{-1} dry weight.

Determination of ethylene production

Rose flowers were individually weighed and placed in 700 ml air tight glass vessels fit with gas sampling ports. The vessels were kept at 22 °C and 70-80 % RH for 2 h. Gas samles (1 ml) were withdrawn from the headspace of vessels for ethylene determination. Ethylene content of the samples was quantitatively analyzed by gas chromatography using a Packard 427 GC, which was equipped with an aluminum oxide column (1/8 inch x 1 m) and a flame ionization detector. The injector, column, and detector temperatures were 80, 100 and 220 °C, respectively (Heiser *et al.* 1998). Ethylene values were indicated as (nl g^{-1} h^{-1}) and each treatment comprised three vessels.

Membrane stability index (MSI)

Flower samples from each treatment were taken on the 1st, 3rd, 5th and 7th days from the beginning of the experiment for determining ions leakage by using the method described by Sairam *et al.* (1997). Two samples (0.2 g) were taken and placed in 20 mL of double distilled water in two different 50 mL flasks. The first one (C_1) was kept at 40 °C for 30 min while the second (C_2) was kept at 100 °C in boiling water bath for 15 min. The electric conductivity was measured with a conductivity meter. The leakage of ions was expressed as the membrane stability index according to the following formula, MSI = [1- (C_1/C_2)] X 100.

Malondialdehyde determination (MDA)

Flower MDA content was spectrophotometrically measured by the method of Hodges *et al.* (1999) at days 1, 3, 5, and 7. The concentration of MDA was estimated by using the formula: MDA content = 6.45 × (A_{532} - A_{600}) - 0.56 × A_{450}, where A_{450}, A_{532} and A_{600} are the absorbance at 450, 532 and 600 nm, respectively and were expressed as µmol mL^{-1}.

Statistical analysis of results

Five treatments of three replicates each, in this experiment, were arranged in a completely randomized design. The experiment was performed twice and had qualitative and quantitative similar results. Analysis of variance (ANOVA) was performed using SPSS program Base 9, SPSS Inc. USA. Means were compared by using Duncan multiple range test at 0.05 level.

RESULTS

Vase life

1-MCP treatment was very effective in extending the vase life of both rose cultivars compared to the control (Table 1). However, the response to 1-MCP concentrations was differed be-

Table 1. Effect of 1-MCP on the vase life and weight loss of *Rosa hybrida* L. cvs. Happy Hour and Bordeaux.

Treatments	Happy Hour cultivar		Bordeaux cultivar	
	Vase life (Days)	Weight loss (%)	Vase life (Days)	Weight loss (%)
Control	3.36 c	19.56 a	4.47 c	16.45 a
1-MCP 0.3 g m^{-3}	5.66 b	14.67 b	6.56 b	13.56 b
1-MCP 0.4 g m^{-3}	10.45 a	2.33 c	7.37 b	10.38 c
1-MCP 0.5 g m^{-3}	10.33 a	2.66 cd	9.22 a	3.79 d
1-MCP 0.6 g m^{-3}	9.66 a	3.56 d	8.89 a	4.12 d

*Means followed by different letters are significantly differ for each other according to Duncan multiple range test at P< 0.05.

tween the two cultivars. All 1-MCP treatments significantly increased the vase life of Happy Hour as well as Bordeaux cultivars in comparison with the untreated control. The best treatments in this concern were 0.4 and 0.5 g m-3 which resulted in (10.45 and 9.22 days) for Happy Hour and Bordeaux cultivars, respectively. The lowest values in this respect (3.36 and 4.47 days) were obtained by control flowers in the first and second cultivars, respectively (Table 1).

Weight loss

The results of Table 1 show that 1-MCP treatment positively influenced the weight loss as expressed of initial fresh weight of both cut rose cultivars. All concentrations of 1-MCP significantly minimized the percentage of weight loss in comparison with the control. After three days from the beginning of the experiment, the control flowers of Happy Hour cultivar lost 19.56 % from the initial weight, however the flowers lost only 2.33 % when treated with 1-MCP at 0.4 g m-3. The minimum weight loss for Bordeaux cultivar was obtained by 1-MCP at 0.5 g m-3 which resulted in 3.79 % in comparison with 16.45 % for the control (Table 1).

Relative water content (RWC)

The effect of different 1-MCP concentrations on the flower RWC was presented in (Fig. 1). RWC recorded at different days of vase life declined at all time points in all treatments for both cut rose cultivars. However, 1-MCP treatment significantly retarded this decline in flower RWC compared to the control. The differences between 1-MCP treatments were clearly appeared after the third day in both cultivars. The best treatments in this concern were 1-MCP at 0.4 and 0.5 g m^{-3} for Happy Hour and Bordeaux cultivars, respectively.

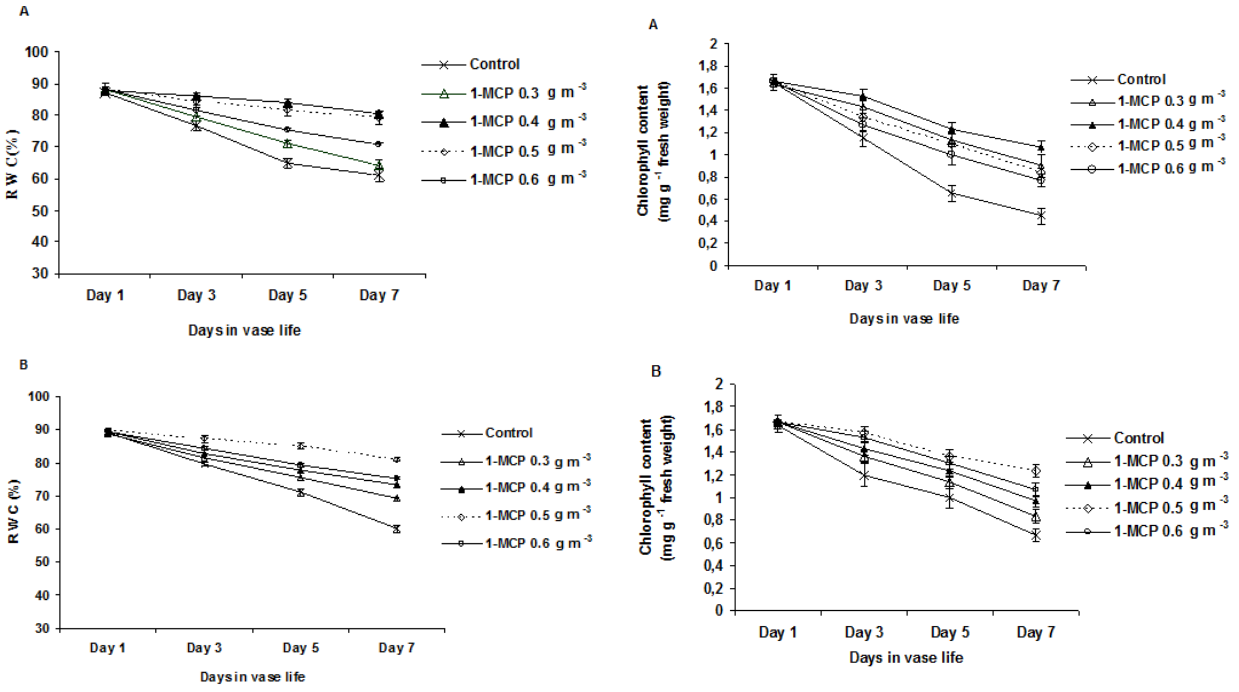

Fig. 1. Effect of diffrent concentrations of 1-MCP treatment on the flower relative water content (RWC) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

Fig. 2. Effect of diffrent concentrations of 1-MCP treatment on the chlorophyll content (mg g^{-1} fresh weight) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

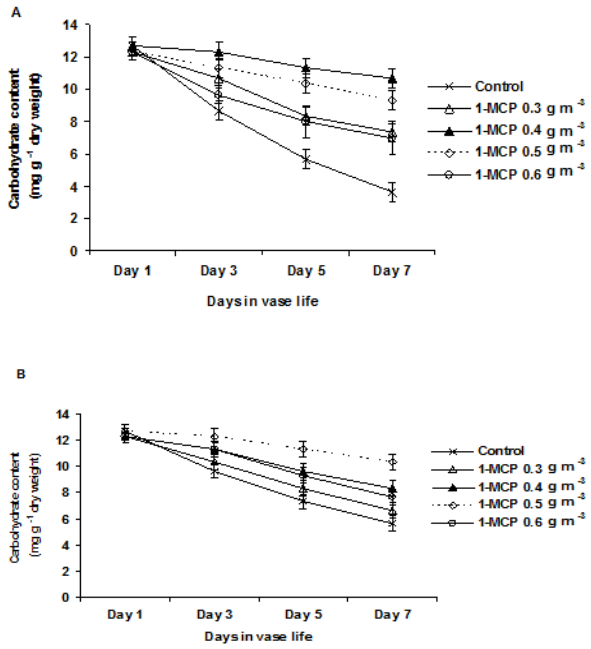

Fig. 3. Effect of diffrent concentrations of 1-MCP treatment on the carbohydrate content (mg g^{-1} dry weight) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

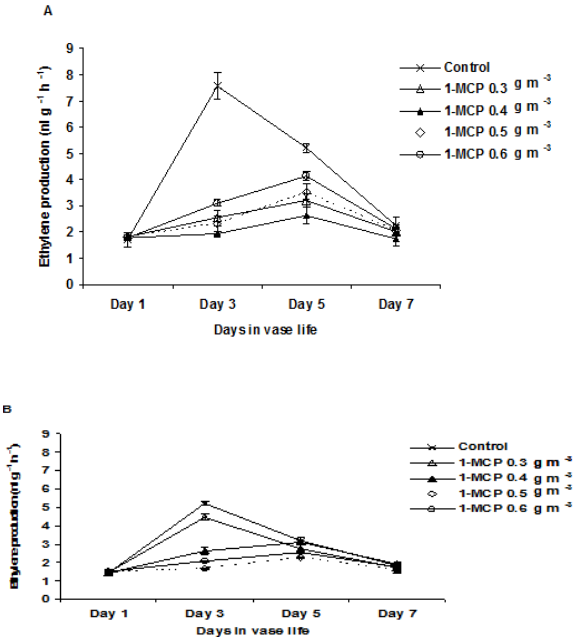

Fig. 4. Effect of diffrent concentrations of 1-MCP treatment on ethylene production (nl g $^{-1}$ h $^{-1}$ fresh weight) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

Chlorophyll content

The total chlorophyll content of leaves was gradually declined with increasing the days in vase life evaluation, however a sharp decrease in chlorophyll content was observed in untreated control of both cultivars (Fig. 2). 1-MCP treatment significantly reduced the chlorophyll degradation compared to the control in both cut rose cultivars. The best treatment in this respect for Happy Hour cultivar was 1-MCP at 0.4 g m^{-3} , however it was 0.5 g m^{-3} for Bordeaux cultivar (Fig. 2).

Carbohydrate content

The effect of various 1-MCP treatments on the total carbohydrate content of flower petals of Happy Hour and Bordeaux rose cultivars was recorded in Fig. 3. The carbohydrate content of untreated control was sharply reduced from the beginning of the experiment in both cultivars. Meanwhile, applying 1-MCP significantly retarded this reduction of carbohydrate during the period of vase life evaluation in both cultivars compared to the control. The effect of 1-MCP on retarding carbohydrate degradation was higher in Happy Hour cultivar than Bordeaux cultivar (Fig. 3). The highest carbohydrate contents were obtained by using 1-MCP at 0.4 and 0.5 g m^{-3} for Happy Hour and Bordeaux cultivars, respectively.

Ethylene production

The ethylene production of both rose cultivars was significantly inhibited by applying 1-MCP treatment compared to the control (Fig. 4). The ethylene production of control flowers in both cultivars was sharply increased and reached its maximum value at the third day of the experiment and decraeased thereafter. The ethylene production of Happy Hour cultivar was higher than Bordeaux cultivar. Intrestingly, in Happy Hour cultivar, all 1-MCP treatments delayed and inhibited the peak of ethylene production and the lowest ethylene production was obtained by using 0.4 g

m^{-3} . However, in Bordeaux cultivar, a climacteric-like peak in ethylene production was observed on the third day by using the lowest level of 1-MCP as happened for the control, while the other levels of 1-MCP significantly inhibited the ethylene production. The best treatment for this cultivar was 0.5 g m^{-3}.

Membrane stability index (MSI)

Results of Fig. (5) indicate that 1-MCP treatments significantly retained the MSI compared with the control which lost their MSI upon the progression of flower senescence during vase life period. The highest MSI was recorded by using 1-MCP at 0.4 and 0.5 g m^{-3} for Happy Hour and Bordeaux cultivars, respectively. At day 7 in Happy Hour cultivar, the MSI for control flowers was 68.70 % compared with 75.38, 92.91, 91.82 and 88.69 % for 1-MCP treatments at 0.3, 0.4, 0.5 and 0.6 g m^{-3}, respectively. While in Bordeaux cultivar the previous values were 76.84, 81.17, 90.81 and 85.49 % compared with the control (68.54 %).

Malondialdehyde content (MDA)

In control flowers, a significant increase in MDA content was observed and reached its maximum value by day 5. However, treatment with any 1-MCP level significantly inhibited MDA accumulation relative to the control in both cultivars (Fig. 6). The lowest MDA content was obtained by using 1-MCP at 0.4 or 0.5 g m^{-3} for Happy Hour and Bordeaux cultivars, respectively.

DISCUSSION

This experiment has demonstrated the commercially significant differences in the longevity of two cut rose cultivars that are presently used by the trade. Pretreatment with 1-MCP significantly extended the vase life and minimized the weight loss of Happy Hour and Bordeaux cultivars under

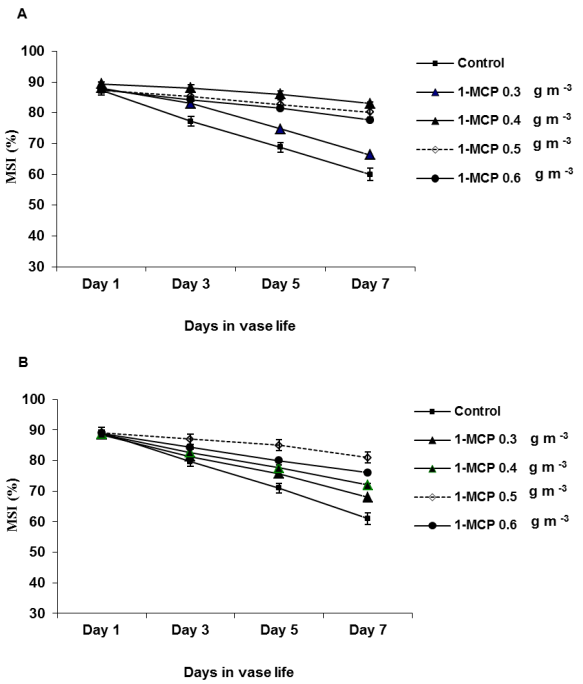

Fig. 5. Effect of different concentrations of 1-MCP on membrane stability index (MSI %) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

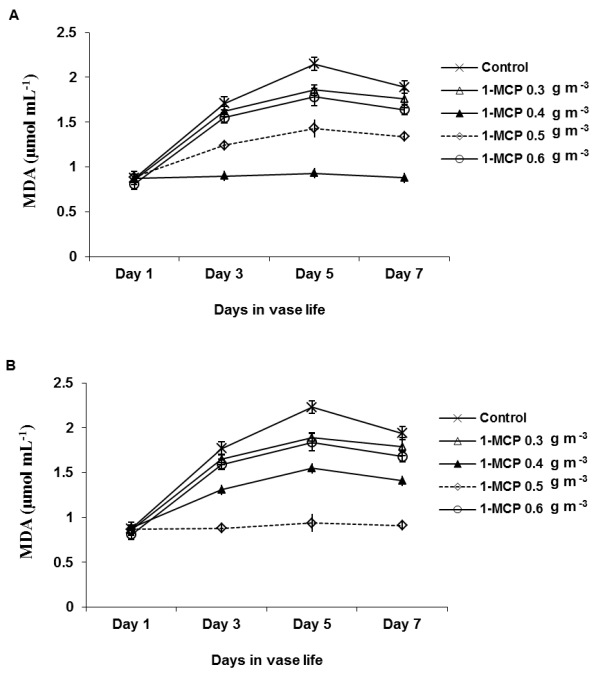

Fig. 6. Effect of different concentrations of 1-MCP on malondialdehyde (MDA µmol mL^{-1}) of *Rosa hybrida* L. cvs. Happy Hour (A) and Bordeaux (B). 1-MCP treatments were applied for 18 h. Control flowers were placed in air in a container identical to those used for the 1-MCP treatment for the same period. Values are means of 3 replicates and each point represents mean ± S.E.

simulated transport (Table 1). These results could be explained through the effect of 1-MCP on maintaining higher RWC compared to the control as shown in (Fig. 1). The senescence-related processes including chlorophyll as well as carbohydrate degradation were significantly retarded by 1-MCP treatment (Figs. 2 and 3). These positive results on postharvest quality confirmed other results on different cut flowers (Uthaichay *et al.*, 2007; Hassan *et al*., 2004; Celikel and Reid, 2002; Picchioni *et al*., 2002)

The ethylene production by both cultivars was significantly inhibited as a result of 1-MCP treatment (Fig. 4). These results were in accordance with the results of Uthaichay *et al*. (2007) who mentioned that, 1-MCP not only inhibited ethylene action but also inhibited ethylene production. The high ethylene production by untreated control, might be adequate to explain the effect of 1-MCP on the vase life of both cultivars. These results further supported the hypothesis that 1-MCP competes with ethylene for bonding to the receptor, and the assumption that the affinity of 1-MCP and the receptor is much higher than that of ethylene and the receptor (Sisler and Serek, 1997). Contrary to the conclusions of Reid *et al*. (1989 a, b), these results suggest that ethylene is an important natural regulator of flower senescence, at least in some rose cultivars. Similar findings were obtained by different authors (Uthaichay *et al*., 2007; Valenzuela-Vazquez *et al*., 2007; Chamani *et al*., 2005; Hassan *et al*., 2004).

We observed that the Happy Hour cultivar was more sensitive than Bordeaux cultivar since the first cultivar was responded to lower concentrations of 1-MCP than the second cultivar. In addition, the ethylene production of Happy Hour cultivar was higher than Bordeaux cultivar (Fig. 4). These results may be due to the variation in ethylene sensitivity under simulated transport between the two cut rose cultivars investigated in this experiment. The variation in vase life between the two cultivars partly appeared to be a result of differences in ethylene production or sensitivity to ethylene exposure (Muller *et al.*, 1998). Other researchers have also demonstrated that the involvement of ethylene in senescence of some flowers may depend on cultivar (Muller *et al.*, 1989 and Hunter *et al.,* 2004) and consequently, the effect of 1-MCP, as an ethylene action inhibitor, will differ according to the cultivar.

In addition to anti-ethylene effects of 1-MCP, in view of our results it may alleviate lipid peroxidation and hence maintained membrane stability. Maintenance of membrane stability in response to 1-MCP application most likely due to induced reduction of lipid peroxidation. This is supported by a lower level of MDA after 1-MCP treatment. MDA is a biomarker of lipid peroxidation (Bailly *et al.*, 1996). Reduced lipid peroxidation probably mitigates rose flower senescence in response to 1-MCP treatment, which is consistent with the finding of Hassan and Ali (2014) who indicate 1-MCP role in reduced lipid peroxidation. It is important to mention that reduced lipid peroxidation and retained membrane stability have been demonstrated to be inversely proportional with flower senescence (Hatamzadeh *et al.*, 2012).

CONCLUSION

From these results, it can be assumed that 1-MCP is an important practical tool for increasing the postharvest life after ethylene exposure that may, for example, result from contamination during transport. The ability to mix ethylene sensitive and ethylene producing commodities can be increased by applying 1-MCP treatment and hence expand export opportunities.

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